BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 03067

SUBJECT: An Extension of the Study of MSFN Configurations for Coverage of Skylab Missions - Cases 900 and 620

DATE: March 23, 1970

FROM: J. P. Maloy

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(NASA-CR-112736) AN EXTENSION OF THE STUDY OF MSFN CONFIGURATIONS FOR COVERAGE OF SKYLAB MISSIONS (Bellcomm, Inc.) 16 p
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ABSTRACT

This report is an extension of a previous memorandum entitled, "Study of Four MSFN Configurations for Coverage of 56 Day AAP Mission," dated December 31, 1969.

Additional computer data including different inclination angles of the orbital plane were collected and analyzed beyond that reported in the previous memorandum and additional analyses were made of the previous data. Particular attention was paid to the amount of lost Apollo Telescope Mount data (due to gaps in coverage greater than 90 minutes) as a function of the inclination angle of the orbital plane. It was found that the amount of data lost because of limited MSFN coverage rapidly increases for inclination angles of the plane of the Skylab orbit between 45° and 50°. This is in general agreement with an MSC study entitled, "A Study of the MSFN Station Coverage for AAP, Utilizing a Santiago, Chile, Facility," dated October 29, 1969. This sharp increase occurs in this region of inclination angles regardless of the exact location of the insertion point and whether Guaymas (GYM) is used in lieu of Texas (TEX) MSFN station.

The percent of unique MSFN contact time over the mission is included for the various inclination angles. The results show (1) that this contact time decreases slightly (<4%) when the minimum allowable contact time per station is increased from three to five minutes and (2) that the total contact time decreases significantly (>20%) when the MSFN site masking (elevation) angle is increased from 2° to 5°.

Other items considered include (1) constant elevation masking angle at the MSFN station versus a variable mask, (2) the accuracy of projecting data for a shorter mission to a 56 day mission, and (3) the antenna keyhole effect.

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MEMORANDUM FOR FILE

INTRODUCTION

Additional computer data was analyzed to extend the study whose results were discussed in my previous memorandum entitled, "Study of Four MSFN Configurations for Coverage of 56 Day AAP Mission," dated December 31, 1969. Emphasis was placed on determining how the amount of lost Apollo Telescope Mount (ATM) data varies with inclination angle. Data was assumed to be lost when the gap between station contacts exceeds 90 minutes, which is the capability of the tape recorders used in the ATM. The previous study had examined only two inclination angles, 35° and 50°. The present study looked at others in that range to determine where a significant coverage variation occurred. It used the 12-station MSFN network (including Santiago) or the nine-station network (including Santiago, but minus three 85 ft. antenna stations at Goldstone, Madrid and Honeysuckle). A 2° elevation angle at acquisition and loss of contact and a minimum contact time of five minutes was assumed.

In addition, it was of interest to determine how the percent unique network contact time over the mission varied within this range of inclination angles (35° and 50°). The computer was programmed to output the total unique (excluding overlapping coverage) contact time of the MSFN. From the accumulated printouts and additional computer runs, other items of interest developed such as limited data on how percent of unique network contact time varies with (1) a change in the minimum allowable MSFN station contact time (three minutes vs. five minutes), (2) a change in elevation masking angle (two degrees vs. five degrees), and (3) a change in the location of the orbital insertion point for the mission (actual insertion point down range vs. a hypothetical start in orbit over Cape Kennedy).

Finally, the accumulated data permitted investigation of the effects of (1) assuming constant elevation masking angle at the MSFN station vs. the realistic variable mask, (2) the accuracy of projecting shorter duration mission data to a 56 day mission, and (3) the effect of antenna keyhole on station coverage, including the effect of changing the keyhole size from 15° half-angle to 6° half-angle at the 30 ft. antenna MSFN stations.

LOST DATA VS. INCLINATION ANGLE

Figures 1 and 2 show a plot of the total ATM data lost in minutes for inclination angles between 35° and 50°. Figure 1 shows the case where 12 stations were employed in the network (the Apollo 12 Manned Space Flight Network plus Santiago). For comparison purposes, superimposed on the figure is data from an MSC study entitled, "A Study of the MSFN Station Coverage for AAP, Utilizing a Santiago, Chile, Facility," dated October 29, 1969. The legend points out the differences in the basic assumptions for the MSC and Bellcomm study. Although the Bellcomm data is for 56 days, the other parameters of elevation angle and minimum contact time as contrasted to the MSC inputs tend to reduce the amount of lost data. The comparison of these two curves is not valid as far as the absolute amount of lost data time is concerned, but is made to compare the orbital inclination angle where there is a marked increase in the amount of lost data. This point occurred at about 48° inclination angle for the 56 day Bellcomm data and at about 47° for the MSC ten-day data.

Some of the MSC data is also plotted in Figure 2, which shows the nine-station case (omitting the three 85 ft. antenna stations). There is relatively little increase in the amount of lost ATM data between 35° and 47°, but at angles a little greater than 47°, there is a significant increase and further increases at 48°, 49° and 50°. Similar selected runs were made using the Bellcomm program assuming 100% probability that a station would be up and working when required. In one case, the network was the same as that assumed by MSC and in the second, the Texas station was substituted in lieu of Guaymas (GYM). These results are also shown in Figure 2, and the curves are similar to MSC's in that there is a significant increase of lost data when a certain inclination angle is reached -- in these instances, at about 45°.

Table 1 has the amount of ATM data lost for inclination angles tabulated for both studies. Three runs at 48°, 49° and 50° inclination for the 12-station case were made assuming a hypothetical insertion into a 235 nm circular orbit over Cape Kennedy, instead of the more normal down range insertion point to determine the effect of starting point on coverage. The amount of lost data was very nearly the same, and the percent of unique network contact time, as shown in Table 2, was almost identical and supports a conclusion that, for the orbits evaluated, over a long duration mission the exact location of the orbital insertion point makes very little difference in overall coverage results, such as the amount of lost data and percent coverage. Also, Table 1, for the nine-station case, gives the comparison data between the use of Texas station (TEX) instead of Guaymas (GYM). It can be seen that although the figures are noticeably different over the inclination angles compared (reflected also in Figure 2), the sharp rise in lost ATM data occurs at approximately the same inclination angle, i.e. 45°.

PERCENT CONTACT TIME VS. INCLINATION ANGLE

Table 2 shows the percent unique network contact time (non-overlapping coverage) for each nominal inclination angle examined in this study. Columns two and three show a comparison of this parameter when the minimum acceptable contact time is three minutes and five minutes for two inclination angles 35° and 50° for a 2° constant mask angle. The difference between the columns gets greater as the inclination angle gets greater, but does not exceed 4% at 50° inclination angle, with less contact time when the minimum permissible contact time is five minutes.

Columns three and four in this table make a similar comparison with respect to different constant mask angles when the minimum contact time was five minutes. The data for all inclination angles studied was available for the 2° case, and it can be observed that the percent contact time is a maximum of 36.0% at 35° inclination angle and decreases to 30.9% at 50° inclination. The percent coverage is less, as might be expected, when the masking angle is 5°, as shown in the table, for the two cases for which data were available, at 35° and 50°. The amount of difference between the columns exceeds 20% in each case.

Finally, the data at the bottom of Table 2 compares the percent coverage using two different locations for insertion to orbit -- one at the normal down range location and the second at a hypothetical location above Cape Kennedy. As mentioned previously, these insertion point locations had very little effect on total mission coverage as can be seen in the table.

CONSTANT VS. VARIABLE MASK

Additional data that was collected and tabulated formed the basis for comparison of the number of contacts and contact time [for a limited number of stations and revolutions (60)] for (1) a constant elevation mask angle of 2° at an MSFN station and (2) actual mask angle (0° above local terrain horizon) based on site masking data obtained from GSFC. The results are shown in Table 3 and can be seen to be erratic due to the nature of the actual masking.

The number of contacts using the variable mask angle was less in most cases. The MSFN station at Cape Kennedy was the only station of the six that showed an increase. However, all of the stations showed either an increase or almost no change in contact time, indicating that when contact was made with variable masking that the duration was longer than when using a constant mask angle of 2°.

DATA PROJECTIONS

A number of comparisons have been made using data for 60 revolutions (approximately four days) and projecting it to 56 days by multiplying by the appropriate factor (approximately 13.4) and comparing with the 56 day results. These figures are shown in Tables 4 and 5. It can be seen in Table 4 that the average percent difference for the number of USB contacts is 5.5% above the actual. When considering USB stations, a 5° mask angle was used. For VHF comparisons, the projected number of station contacts is 4.5% on the average above the actual.

Table 5 shows a similar analysis with respect to the number of gaps. The percent deviation is much greater and much more erratic, indicating that it could not be accurate to project a 60 revolution-gap-count to 56 days (808 revolutions). If one gap is not counted since it may be at the end of the 60 revolution period, then the total for 56 days would be off by 13 or 14.

KEYHOLE EFFECT

Finally, an analysis of the effect of antenna keyholes on USB contacts in the 56 day mission was made. Results are shown in Table 6 and point out that the effect is negligible as far as reducing contacts below the minimum required is concerned. There were only two such contacts Guam (GWM) for the 35° inclination case and four for the 50° inclination case -- two at Bermuda (BDA) and two at Santiago (AGO) -- although there were considerably more contacts that were foreshortened by a keyhole either at the start of a contact or at the end. The three 85 ft. antenna stations had by far the greatest number of keyhole-affected contacts due to the larger size of the keyhole. Madrid (MAD), however, at the 35° inclination angle, had no keyhole-affected contacts due to its latitude (40.5°N) in relation to the inclination angle. The sub-vehicle track did not get high enough to pass through the keyhole at the lower inclination angle, but MAD had the highest number of keyhole-affected contacts at the higher inclination angle of 50°.

The 30 ft. antenna MSFN stations with the smaller keyhole (all have recently been modified to approximately 6°) and their north-south orientation had much fewer keyhole-affected contacts. This is especially understandable when one considers that a 5° constant mask was used for the USB consideration and this would be almost inclusive of the 6° keyhole. Consequently, only a relatively small portion of the keyhole remained to detract from contact duration and this could have been missed due to the size (170 seconds) of the in-range search increment of the computer program.

The last table indicates the improvement that was made in reducing the number of keyhole-affected contacts by reducing the keyhole size from 15° to 6° half-angle. Data is shown for 60 revolutions for 0° and 5° elevation for a sampling of five stations. As can be seen, the change is significant in all cases.

CONCLUSIONS

Several conclusions can be made from the results of this study. Primarily that:

1) As the inclination angle of the Skylab orbital plane increases, the amount of lost ATM data increases slowly with sharp increases occurring after 45°.

2) The unique contact time as a percentage of total mission decreases slightly (<4%) when the minimum allowable contact time per station is increased from three to five minutes.

3) The percent of unique contact time decreases significantly (>20%) when the MSFN site masking angle is increased from 2° to 5°.

Some additional conclusions are:

1) Use of an actual elevation mask in place of a constant mask will yield different results per

station, but the overall network coverage is essentially the same especially at the higher constant mask angle (5°).

2) That projections from what might be considered a repetitive cycle (60 revolutions or ten days) to a full duration mission of 56 days are accurate enough for the number of contacts and contact time, but can be very misleading in regard to number of gaps and accordingly to the amount of lost data.

3) That antenna keyholes are not a significant factor in the coverage consideration, especially since the keyhole size at the 30 ft. stations has been reduced from 15 to 6 degrees half-angle.

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2034-JPM-drc J. P. Maloy

Attachment
Figures 1 and 2
Tables 1 thru 7

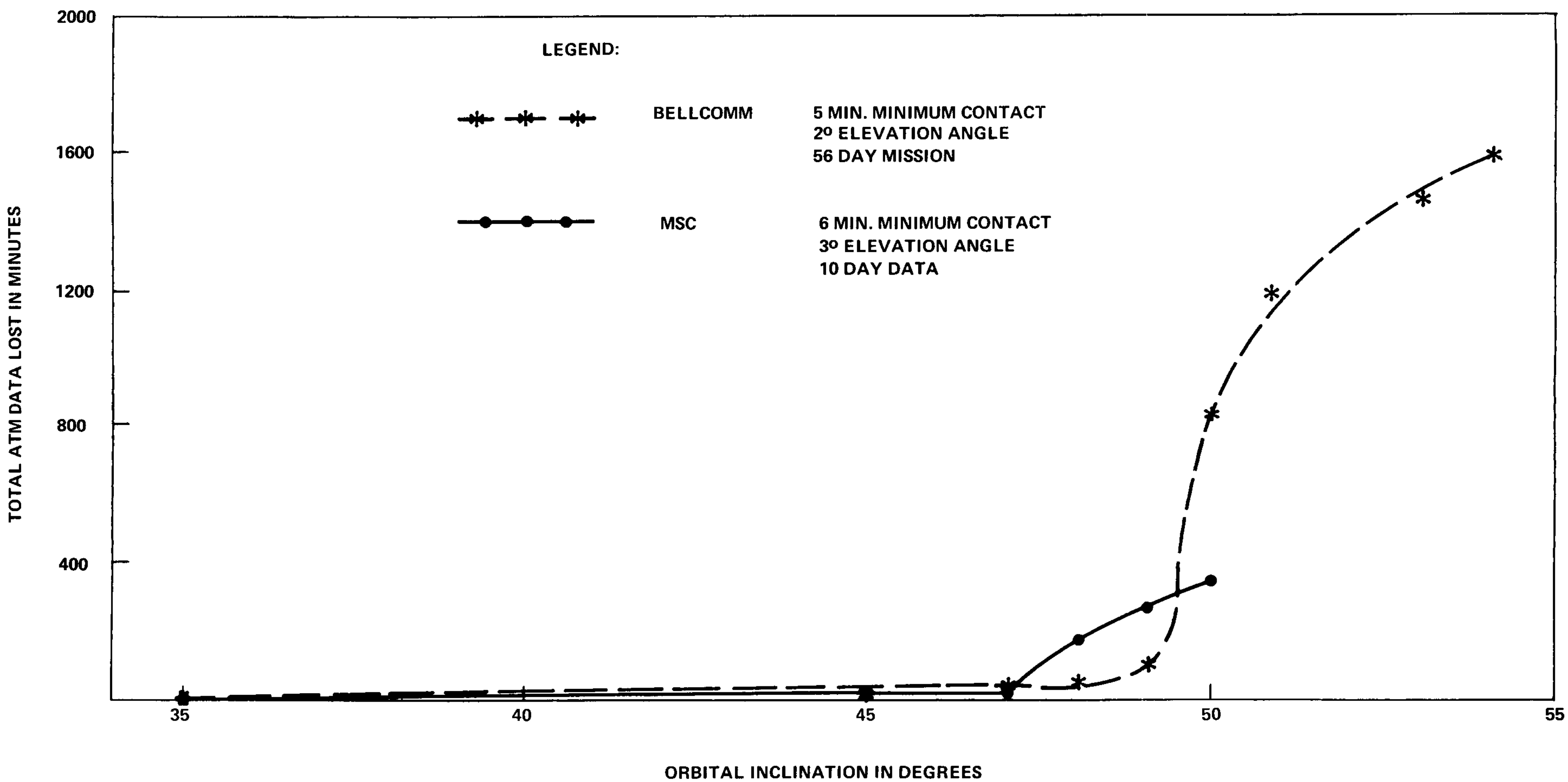

FIGURE 1 - AMOUNT OF ATM DATA LOST VS. INCLINATION ANGLE
(12 STATIONS INCLUDING SANTIAGO)

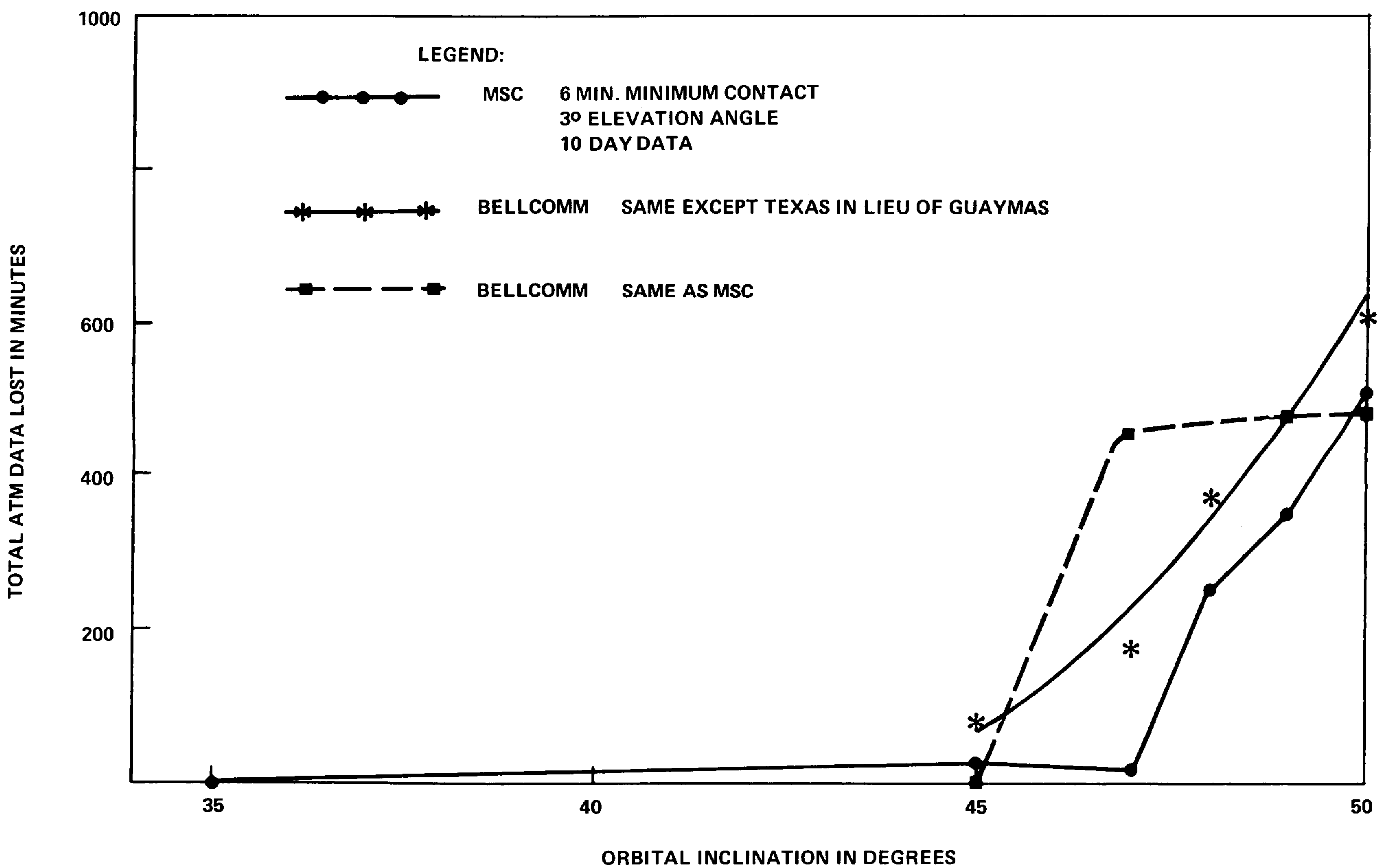

FIGURE 2 - AMOUNT OF ATM DATA LOST VS. INCLINATION ANGLE FOR 10 DAY MISSION (9 STATIONS INCLUDING SANTIAGO)

TABLE 1

ATM DATA LOST
(in Minutes)

12 Stations

Nominal Inclination	MSC Analysis	Bellcomm Study: Start at Insertion Point	Bellcomm Study: Start at Cape Kennedy
35	.2	0	No Data
45	27.3	16.1	No Data
47	20.0	49.8	No Data
48	175.0	66.1	68.7
49	274.0	91.1	90.8
50	348.0	835.0	755.0

9 Stations

Nominal Inclination	MSC Analysis	Bellcomm Study: With TEX (No GYM)	Bellcomm Study: With GYM (No TEX)
35	.2	No Data	No Data
45	28.0	80.2	8.8
47	20.0	176.2	460.7
48	249.0	373.1	No Data
49	348.0	No Data	483.1
50	504.5	603.0	486.7

TABLE 2

UNIQUE MSFN CONTACT TIME
(Percent of Total Mission Time)

Altitude 235 nm

(12 Stations)

Inclination Angle	Minimum Contact Time 3 Min.(2° Mask)	5 Min.(2° Mask)	5 Min.(5° Mask)
35°	36.7%	36.0%	28.6%
45°	No Data	33.8%	No Data
47°	No Data	33.0%	No Data
48°	No Data	32.6%	No Data
49°	No Data	31.9%	No Data
50°	32.1%	30.9%	22.4%

(2° Mask; 5 Min.Contacts)
Insertion

Inclination Angle	Down Range	Cape Ken.
35°	36.0%	No Data
45°	33.8%	No Data
47°	33.0%	No Data
48°	32.6%	32.5%
49°	31.9%	31.9%
50°	30.9%	31.0%

TABLE 3

MSFN COVERAGE COMPARISON

CONSTANT 2° MASKING VS ACTUAL MASKING
(60 Revs.)

Number of Contacts:

Sta.	2°	Actual	Δ
CRO	31	29	- 2
GWM	24	24	0
ACN	22	18	- 4
MIL	28	30	+ 2
BDA	28	27	- 1
HAW	32	31	- 1

Contact Duration (Mins.):

CRO	267.2	262.5	+ .3
GWM	191.8	202.0	+11.2
ACN	175.5	212.9	+37.4
MIL	254.6	285.4	+30.8
BDA	246.1	244.1	- 2.0
HAW	265.3	308.2	+42.9

TABLE 4

COMPARISON OF ACTUAL NUMBER OF CONTACTS FOR 56 DAYS AND PROJECTED NUMBER FROM 60 REVOLUTION DATA (50° INCLINATION)

USB Sta. (5° Mask)	56 Day # Con.	60 Rev. Proj.	Δ	%Δ	
MIL	249	242	- 7	- 2.8	
BDA	289	310	+22	+ 7.1	
CYI	244	242	- 2	- .8	
ACN	189	175	-14	+ 8.0	
MAD	345	377	+22	+ 5.8	
CRO	228	229	+ 1	+ .4	
GWM	195	202	+ 7	+ 3.5	
HSK	366	390	+24	+ 6.1	
HAW	218	242	+24	+10.0	
GDS	369	390	+21	+ 5.4	
TEX	243	256	+13	+ 5.1	
AGO	298	269	-29	-11.7	Avg. % Dev. = 5.5

VHF Sta. (2° Mask)					
MIL	302	296	- 6	- 2.0	
BDA	399	430	+31	+ 7.8	
CYI	296	309	+13	+ 4.4	
ACN	221	215	- 6	- 2.7	
CRO	275	269	- 6	- 2.2	
GWM	231	215	-16	- 2.6	
HAW	258	269	+11	+ 2.3	
TEX	294	309	+15	+ 2.0	
AGO	398	364	-34	- 8.5	
MAD	365	390	+24	+ 6.6	
HSK	385	417	+32	+ 8.3	
GDS	388	404	+16	+ 4.1	Avg. % Dev. = 4.5

TABLE 5

COMPARISON OF ACTUAL NUMBER OF GAPS EXCEEDING 90 MINUTES

FOR 56 DAYS AND PROJECTED NUMBER FROM 60 REVOLUTION DATA

	35° Inclination				50° Inclination			
USB* Case	56 Day	Proj. 60 Rev.	Δ	%Δ	56 Day	Proj. 60 Rev.	Δ	%Δ
1	128	108	-20	-15.6	97	90	- 7	- 7.2
2	195	148	-47	-24.1	175	161	-14	- 8.0
3	14	13	- 1	- 7.2	47	40	- 7	-14.9
4	69	40	-29	-42.0	93	81	-12	-12.9
VHF* Case								
1	7	13	+ 6	+85.5	40	54	+14	+35.0
2	10	13	+ 3	+30.0	73	67	- 6	- 8.2
3	0	0	0	0	27	27	0	0
4	0	0	0	0	27	27	0	0

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*Case 1: Apollo 12 Manned Space Flight Network: Merritt Island (MIL), Bermuda (BDA), Grand Canary (CYI), Ascension (USB-ACN, VHF-ASC), Madrid (MAD), Carnarvon (CRO), Honeysuckle (HSK), Guam (GWM), Hawaii (HAW), Goldstone (GDS), Texas (TEX)

Case 2: Apollo 12 network minus the three 85 foot antenna stations at MSC, HSK, and GDS.

Case 3: Apollo 12 network plus a new station at Santiago, Chile (AGO).

Case 4: Apollo 12 network minus the three 85 foot antenna stations at GDS, HSK, and MAD, but plus AGO.

TABLE 6

EFFECT OF ANTENNA KEYHOLES ON MSFN COVERAGE
(6° for 30' ant.; 15° for 85' ant.)

USB ONLY

35° Inclination

	Sta.	Number Con.	Number of Keyholes	Contact Eliminated
1	CRO	372	7(s)	0
2	HAW	393	3(s)	0
3	TEX	351	7(s)	0
4	MIL	344	6(s)	0
5	CYI	352	0	0
6	BDA	321	6(s)	0
7	GDS	293	*146(s), 47(e)	0
8	AGO	313	7(s)	0
9	HSK	292	*146(s), 5(b), 51(e)	0
10	GWM	279	8(s), 8(e)	2
11	ACN	257	9(s)	0
12	MAD	243	*0	0

50° Inclination

	Sta.	Number Con.	Number of Keyholes	Contact Eliminated
1	CRO	228	9(s)	0
2	HAW	218	12(s)	0
3	TEX	243	8(s)	0
4	MIL	249	9(s)	0
5	CYI	244	10(s)	0
6	BDA	289	5(s), 2(e)	2
7	GDS	369	*71(s), 17(e)	0
8	AGO	298	4(s), 2(e)	2
9	HSK	366	*72(s), 16(e)	0
10	GWM	195	7(s)	0
11	ACN	189	10(s)	0
12	MAD	345	*101(s), 19(e)	0

(s) keyhole at start of contact

(e) keyhole at end of contact

(b) both

* 85' antenna with 15° half-angle keyhole

TABLE 7

COMPARISON OF NUMBER OF KEYHOLE EFFECTED CONTACTS

KEYHOLE HALF ANGLE OF 15° VS 6°

(60 REVS)

	0° ELEV		5° ELEV	
KEYHOLE	15°	6°	15°	6°
MIL	6	3	3	1
GMB	8	3	3	1
AGO	7	3	6	0
ANG	24	11	13	1
CYI	7	No Data	3	0